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DESCRIPTION OF THE IMMATURE STAGES OF *DIORYCTRIA TAEDAE* SCHABER AND WOOD, WITH NOTES ON ITS BIOLOGY AND THAT OF *D. DISCLUSA* HEINRICH (LEPIDOPTERA: PYRALIDAE)

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Abstract.—Adult emergence in Maryland and Delaware of a pine coneworm, *Dioryctria taedae* Schaber and Wood, indicates two broods per year, one in late August and the other in early October. Observations on the biology of the coneworms feeding on loblolly pine, *Pinus taeda* L., are recorded with brief descriptions of the immature stages. Measurements of the head capsule, body length, and labrum indicate five larval instars. Ten species of Hymenoptera and five of Diptera have been recovered as parasites from the last two larval instars and pupae. Comparative notes on *D. disclusa* Heinrich are also given.

The loblolly pine (*Pinus taeda* L.) industry in Maryland holds a significant place in the economy of the state, and the forests are maintained by planting. Landowners purchase seedlings grown in state forest nurseries from the Maryland Department of Forestry. Seeds are in great demand and must be obtained by collecting cones from the crowns of trees that are cut for lumber each fall. However, the seed supply at the State Forest Tree Nursery in Harmans, Maryland, is extremely limited having been reduced by seed insects to the point where plantings may have to be curtailed.

Because pine coneworms are considered among the most destructive pests of pine cones, various insect surveys were initiated. In Virginia, Knight (1952) and Schroeder (unpublished data) reported that *Dioryctria amatella* (Hulst) destroyed 27% and 45% of the total seed, respectively. *Dioryctria amatella* and *D. disclusa* Heinrich were found to be primary pests of loblolly pine in Mississippi (Neel and Sartor, 1969). *Dioryctria amatella* accounted for 86% of all insects identified attacking mature loblolly pine cones in Georgia (Dohany and Heikkenen, 1968). A study of slash pine cones (*Pinus elliotii* Engelm.) in Florida showed that, although the number infested by *Dioryctria* spp. and *Laspeyresia anaranjada* Miller were about the same, the coneworms were estimated to destroy nine times as many

seeds as the seedworm, *L. anaranjada*, or nearly 25% of the total potential seed yield (Merkel, 1961).

A pine coneworm was discovered infesting second year cones of loblolly pine in Maryland in the early 1960's and was identified at that time as "*D. zimmermani* (Grote)" (Coop. Econ. Insect Rep., 1964).

Subsequently, Schaber and Wood (1971) showed this identification to be incorrect. Because of different morphological characteristics and biological feeding habits exhibited by this species from previously published descriptions, this insect was described as *D. taedae*.

This paper provides detailed descriptions of the egg, larva, and pupa with notes on the biology of the various life stages not included by Schaber and Wood (1971).

Methods and Procedures

The collection of cones was concentrated in Sommerset, St. Mary's, Wicomico, and Worcester counties, Maryland; in Sussex Co., Delaware; and in King and Queen County, Virginia, during the study period, 1967–1970. These counties were selected because continuous logging was in progress for the duration of this study. Although this is not a random design for the collection of the pine cones, it proved less costly than to hire a professional climber. Additionally, even if a climber were in the 18–24 m high trees, he would be unable to see the tips of the branches and, therefore, would be unable to tell if the cones or terminals were infested. Since the forestry practices of the State of Maryland prevent the private cutting of trees, the only successful method that remained was to follow the logging crews from area to area.

Only cones, tips, and leaders that showed signs of damage were collected. Cones were dipped in melted paraffin to delay spoilage and desiccation when used as larval food. Most of the larvae were fed the artificial medium of the fall armyworm (Burton, 1967) modified as suggested by E. O. Thomas (personal communication). These modifications included the following: (1) Addition of inositol, (2) substitution of bacitracin for streptomycin, (3) 3.5 ml of 37% formaldehyde instead of 15 ml of 10% formalin, (4) 14 g of methyl-p-hydroxbenzoate and 14 g of sorbic acid instead of the 8.8 g and 11.8 g, respectively, in 100 ml of 95% ethyl alcohol, (5) no kanamycin sulfate, and (6) in the vitamin mixture, vitamin B_{12} not triturated in mannitol but added directly into the solution.

The larvae, after hatching or collection from the field, were placed in individual 2 oz plastic containers half filled with artificial medium. The larvae were transferred to fresh stock every two weeks because of desiccation of the medium with first- and second-instar larvae and because of the appetite of the later instar larvae. These containers served as pupation chambers as well.

Table 1. Mean measurements of the larval instars of *Dioryctria taedae*. All values in mm.

Instar	N	Head Length	Head Width	Body Length	Labrum Width
1	2	0.20	0.30	2.00	0.10
2	4	0.45	0.57	5.30 ± 1.5	0.20
3	3	0.82	1.16	8.40 ± 0.9	0.30
4	14	1.22	1.68	13.5 ± 1.3	0.50
5	12	1.50	2.10	18.3 ± 2.8	0.65

The rearing chamber was set for 16 hours of light and 8 hours of darkness. The day temperature was 29°C and the night, 18°C. Moisture was added to the growth chamber by placing a 2500 ml beaker of water with a wick formed of wire mesh 15 cm high wrapped with cheesecloth.

Adults were placed in small vials for sex determination and then transferred to breeding cages. These cages were 30 cm cubes and each contained two small vials of 10% sugar water as a food source. After three or four days, the females were removed and placed in individual egg-laying cages. The egg-laying cages were made of two round plastic dishes 95 mm in diameter with the open ends taped together, containing 10 mm of artificial medium as a base. A 0.3 cm, slightly curved mesh screen was placed on top of the medium and covered with cheesecloth. Again, small vials containing sugar water were added. After oviposition had been completed, the female moths were preserved, mounted, and labeled. The young larvae that hatched were placed in individual rearing containers as previously described.

Description of Life Stages

Egg.—Eggs elliptic-oval; average width, 0.55 mm; average length, 1.05 mm. Creamy white when deposited. Embryo clearly visible before hatching. Color gradually changes from white to yellow, to reddish orange, and then to a dull reddish brown before hatching. Surface of egg with rugose appearance due to network of ridges running irregularly over entire surface.

Larva (Table 1).—First-instar average length 2.00 mm upon hatching. Striped and light brown. Compound eyes with small area of very heavy pigmentation, disappearing toward end of first-instar. Second-instar displays same coloration patterns as first-instar. Third-instar uniform in color and may vary from reddish brown to almost black. Fourth-instar generally darker in color than earlier instars. Fifth-instar body color usually black green to purplish overlaid with some pinacula. From each pinaculum, arises a single seta (Fig. 1). Ventrally, body usually buff to reddish brown. Head varies in color from light to dark reddish brown with some maculations. Six lateral ocelli lighter in color than head capsule. Thoracic shield reddish brown and

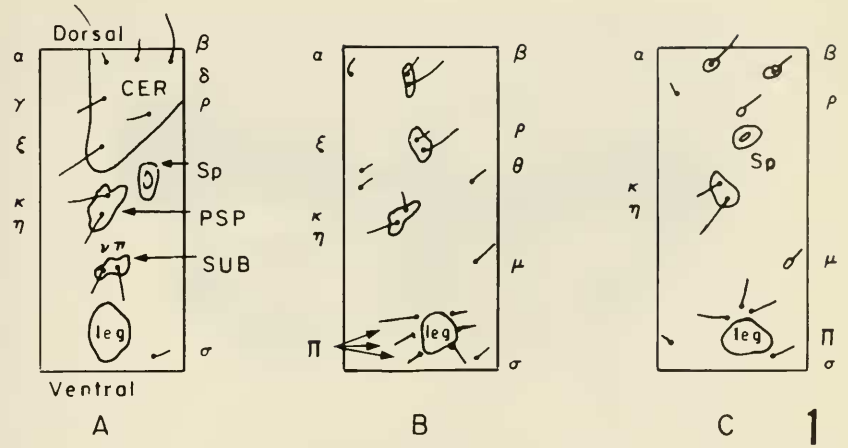

Fig. 1. Schematic of the setal arrangement of the fifth-instar larva of *Dioryctria taedae*. A, Prothorax. B, Metathorax. C, 4th abdominal segment. (Setal terminology follows that of Peterson, 1962.)

Abbreviations

CER — cervical shield
Sp — spiracle
α — alpha
β — beta
γ — gamma
δ — delta
ε — epsilon
ρ — rho
σ — sigma
PSP — prespiracular setae
SUB — subventral group
κ — kappa } PSP
η — eta }
μ — mu
ν — nu }
π — pi } II
τ — tau }

light brown to yellow anteriorly, with yellow mesal line. Three pairs of thoracic legs with simple claws and 4 pairs of prolegs. Anal shield yellowish brown with 6 setae and sclerotized pigmented pits, when viewed microscopically, black. Integument coarsely granulose with large apodemal spots and tubercles on either side. Head of fifth-instar averages 1.5 mm wide and 2.1 mm long. Labrum (Fig. 2) averages 0.65 mm in width, emargination quite deep. Epipharynx (Fig. 2) with many light-colored stout spines. Labrum with 6 toothlike projections and 12 setae. Spinneret relatively stout, about 3.5× as long as wide. Mandibles dark brown to black, and quadradentate. Proleg crochets arranged in circle. Microspines on venter of each segment distinct; perianal region with medium sized, lightly pigmented spines.

Pupa.—Pupa cylindrical, smooth, narrow, varying in length from 14.3 to 15.9 mm (mean 15.3 mm). Mean length of abdominal segments 10.5 mm. Head forming a blunt point, with a pronounced clypeal protuberance. In-

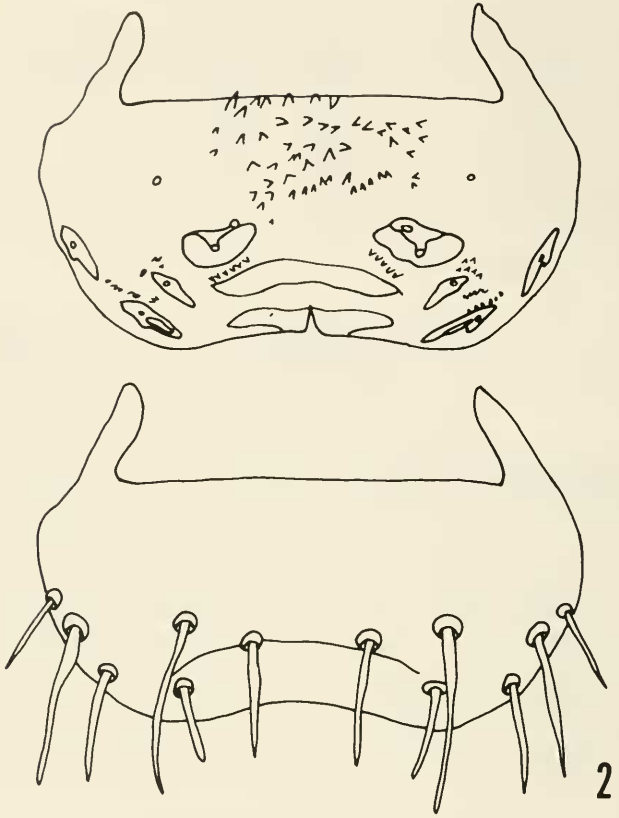

Fig. 2. Fifth-instar larva of *Dioryctria taedae*. Top, epipharynx; bottom, labrum.

tegument smooth, but pro- and mesothorax are wrinkled. Dorsum of metathorax punctate. Dorsal ⅔ of abdominal segments heavily punctate, punctures extending ventrally to midway on segments. Dorsocaudal gibba elongate, black, and elevated, about 3.5 to 4× as long as wide. Dorsum of segment 10, caudad of gibba, darker than dorsum of other segments; sometimes containing an extra pair of setae. Of 90 pupal cases examined, 24 exhibited an extra pair of setae; of these 18 were females and 6 were males. Cremaster expands slightly laterally and contains 6 slender spines with small apical hooks.

Adult.—The complete description and notes on how to distinguish adults from 2 closely related species (*D. amatella* and *D. zimmermani*) have been published (Schaber and Wood, 1971). However, to further aid field identification, the 3 species have been included here for comparison (Fig. 3).

Fig. 3. Adults. A, *Dioryctria taedae*. B, *D. amatella*. C, *D. zimmermani* (western specimen).

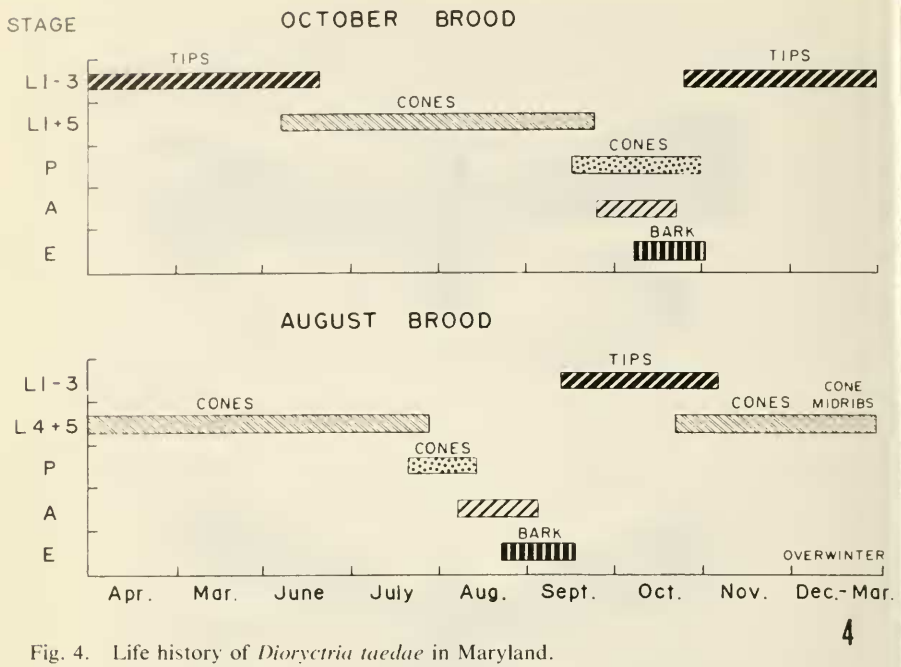

Fig. 4. Life history of *Dioryctria taedae* in Maryland.

Larval Activity and Development

Field-collected larvae of *D. taedae* were taken from flower clusters, second year cones, terminals, or leaders of loblolly pine, rarely from first year cones. Larvae in the first-, second-, and third-instars were taken from terminals and leaders; however, fourth- and fifth-instar larvae were rarely found there. In most cases, fourth- and fifth-instar larvae were taken from second year cones.

Larvae from the October adults infest terminals and, the next spring, they attack developing second year cones. A larva may feed on one or more cones before it completes development. Some larvae of this October brood continue activity, pupate, and emerge with the adults of the October brood, thus there is interbreeding between the two broods of this species (Fig. 4).

Larvae in the field overwinter either as first-/second-instars or as later instars. The young instar larvae (October brood) tunnel into the terminal and spin a hibernaculum very soon after hatching. The older larvae (August brood) eat out the midrib of the second year pine cones and line it with silk. In the spring, they emerge and infest terminals and developing second year cones and emerge as adults in late July to early August.

Pupal Development

The duration of the pupal stage varied from 14 to 33 days. Based on data taken during the summers of 1967 and 1968, there are two pupation periods, in late July to early August and in early September, averaging 18.3 and 23.0 days, respectively (Fig. 4). Duration of the latter period varied from 16 to 26 days. Only one specimen of all larvae, either reared in the laboratory or from the field, pupated between August 16 and September 14.

Of the total number of pupations observed, 53% occurred during the first pupation period of late July to early August and 45% pupated during the second pupation period.

Adult Behavior

Dioryctria taedae exhibits a bimodal life cycle (Fig. 4). Adults emerge in the latter part of August and in the early part of October. *Dioryctria* spp. were observed emerging during these same two periods in Florida (Ebel, 1965) and Georgia (Franklin and Coulson, 1968).

In the fall of 1967, two moths were observed in the grass and low underbrush at the base of a large loblolly pine tree at Willards, Maryland. They were making short abrupt flights of 1 to 2 m, 0.5 to 1 m above the ground, alighting on the vegetation. Extended or high flights, or both, were never attempted in the field or in the laboratory.

Before flight begins, the moths wave their antennae and make fibrillate movements with their wings. Flight begins with an abrupt spring and concurrent fast wing beating, and ends with an abrupt landing, legs clutching the surface with no further movement.

When adults were placed in vials for sex determination, females crawled very little. The males, however, were constantly crawling and attempting to fly.

In June 1965, in Georgia, Dr. Gene Wood (personal communication) noted that several *Dioryctria* specimens were attracted to a black light trap and that the first insect of the evening was a *Dioryctria* sp.

In the laboratory, the female moth, when placed in an egg-laying cage, probed with her abdomen under and into cracks in the artificial medium and around roughened areas of the 0.3 cm mesh screen and cheesecloth. Most eggs were laid on the underside of the screen. Eclosion took place seven to eight days after deposition.

Hosts and Damage

Loblolly pine is preferred to pond pine as host for *D. taedae* in Maryland and Delaware. Attacks on pond pine occurred only at the periphery of heavily infested stands of loblolly pine. It infested only loblolly pine cones

in Virginia and North Carolina (Neunzig et al., 1964a, b) but in Georgia, *D. taedae* (reported as *D. zimmermani*) attacked shortleaf pine, *P. echinata* Mill. (Franklin and Coulson, 1968).

Attacks by the larvae of *D. taedae* were noticed only on older trees, whereas *D. zimmermani* attacked trees of nursery stock age in Illinois and other northeastern states (Rennels, 1960; Schuder, 1960). No damage of nursery stock was caused by *D. taedae*.

Parasites and Natural Control

A species of *Xanthophyto* is the most abundant dipterous parasite found in Maryland and Delaware parasitizing *D. taedae*.

The small parasite, *Hyssopus rhyacioniae* Gahan, is the most prevalent of the Hymenoptera. It produces many offspring from one dead host larva. Small black ants were also noticed within the dead larval skins and tunnels of *D. taedae*; similarly, Schuder (1960) noted small black ants feeding on larvae of *D. zimmermani* in Indiana.

The parasites of *D. taedae* noted were:

Hymenoptera.—Braconidae: *Macrocentrus dioryctriae* Muesebeck; *Meteorus tetralophae* Muesebeck; *Bracon* sp.; *Apanteles aristoteliae* Viereck. Eulophidae: *Hyssopus rhyacioniae* Gahan. Ichneumonidae: *Charops annulipes* Ashmead; *Lissonota* spp. (two species); *Exeristes comstockii* (Cresson); *Campoplex* sp.

Diptera.—Tachinidae: *Xanthophyto* sp.; *Phrynofrontina* sp.; *Phrynofrontina discalis* (Coquillett). Cecidomyiidae: Unidentified species.

Other Species Found in Association with *D. taedae*

Only seven specimens of *D. disclusa* were captured within the study area during 1967 and 1968. Larvae of this species were found infesting second year cones of loblolly pine. The larvae pupated in mid-May and emerged in June.

The pupal case from the first abdominal segment to the end of the cremaster averaged 9.5 mm in length and darkens with age to become a dark reddish brown. The average period of pupation was 16 days.

Because no adults were captured or emerged later than the middle of June during four years (1965–1968) of intensive collecting, there is probably only one generation per year in Maryland. In Mississippi, adult moths emerged during a similar two week period extending from the third week in May to the first week in June. No moths emerged after this time, even though collection of damaged cones was carried out until October (Neel and Sartor, 1969). Due to its low relative abundance, *D. disclusa* is apparently not a major factor in pine seed reduction.

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